

SIMGRUA – A VIRTUAL SIMULATOR FOR TRAINING

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The development of a simulator for training, based in a virtual environment, composed for software 3D and specific interaction physical devices of the virtual reality, must have a development process suitable to the difficulties of construction of these systems. On the other hand the architecture of the system must follow to the maximum the real system in what it respects of that tasks: navigation, selection, manipulation and system control. On the other hand, the choice and evaluation of physical devices that interact with users is critical to system success.

It is intended with this document to demonstrate the development process and the architecture of a simulator of a crane of the marble quarries, that was implemented, and have as purpose to help two groups of users in their learning process: operators of cranes that intend to recycle its abilities and pupils that intend to get professional qualification in operator of cranes.

He also intends with this system, for besides promoting the learning of its users, effecting its evaluation of the performance to the cognitive and psychomotor domains. Some tests with users had been implemented who had demonstrated that the operation and satisfaction level is positive and can harness its process of teaching and learning with cranes.

1 Introduction

The extraction industry of marbles existing in Portugal, more concretely in the Alentejo region, has to its service a set of techniques, human resources and equipment, specialized in the tasks of translate marble stones in its quarries. The execution of these tasks is made in a physical environment that contains many physical risks, because the majority of the machines have great dimensions, the workers works in great heights and stone blocks would provoke crushings in its employees due its great weights.

In the quarry exists a equipment called crane, that is responsible for the translation of the marble stone blocks, between deep of the quarry and the park of blocks and that it demands a very careful and accurate operation. For that, crane operators must have adequate a professional training that allows them to acquire all the knowledge and abilities in the operation of these machines. This article intends to demonstrate some aspects related with the development of a virtual simulator, called SimGrua, that supports the professional training, initial and continued, of crane operators in marble quarries. The SimGrua is based on the use of the technologies that support virtual environments and was developed an appropriate software, that uses adequated physical devices and interaction techniques. It is important to relate that the development of these systems involves some areas of the knowledge, proper and similar, as they are the case of the human factors, person-machine interface, ergonomics, social impact, hardware and software [1].

The main aspects that we want to report in this document are related with the use of some methodologies in the development of the system and with the functional architecture where the system was based.

2 Problem description

The professional training of crane operators in Alentejo region, is based currently in one theoretical component and one eminently practical component, where this last one requires the operation of those equipment in work context. Thus, currently the practical part is based exclusively on the operation with real cranes, where the pupil, with the aid of teacher, learns to execute the proper tasks of crane operator function. However, this practical training is not clearly safety for its participants and equipments, being able

to be complemented and to be improved, with all the certainty, through the use of a simulator based on a virtual environment.

The crane is an equipment of great dimensions and sufficiently heavy, one of the most expensive equipment of the extractive area and where its mobile and articulated components can accede different areas of the quarry, occupying great percentages of its total area. An error of operation with this equipment can damage the structure of the crane, partial or total, and put the physical integrity of people and goods that are in its area of influence.

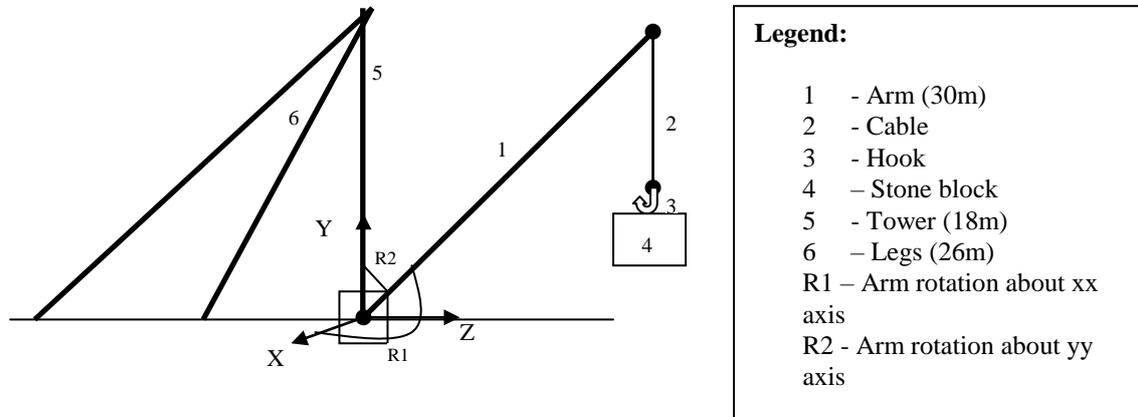


Figure 1. Main components and articulations of crane structure

Thus, to develop training in this context can provoke situations of lack of security for people and systems, with the respective costs associates, thus being able to constitute an inhibiting factor of the pupils learning and a limitation for the teachers education methods. The use of virtual environments technologies in this area , can also raise sufficiently its effectiveness for diverse reasons:

- The pupil can simulate all type of possible tasks and inside each one of them it can execute all the actions that to intend, that not cause any damages to the system;
- The pupil can develop its our learning to its proper rhythm, without needing teacher presence and without the limitations to be in context of work in the quarry;
- The system can detect pupil operation errors and informs teachers with detailed information about its causes and results of that actions;
- The training sessions can be saved (visualization, sound and operation data) to be analyzed by pupil and teacher, as way to be corrected the pupil errors;
- The system can execute formal and informal sessions of pupil evaluation, with different levels of difficulty, previously defined in the system by teacher.
- the real system that if it intends to reproduce virtually, is composed for an involving physical space, the quarry, that has a set of static and dynamic objects in its interior, and people who play their tasks. In this system, the main elements are the crane and the people that manipulate it. Thus, in this work are explored the following crane attributes: physical structure, functional capacities and behaviors replies to the operators and objects actions. The tasks that this system tries to reproduce, are executed for crane operator and an assistant, whom normally located in the deep one of the quarry, help operator to translate stone blocks. Thus, it is given special attention to the interaction types that the operator establishes with the involving environment, the crane and with others workers in the space of the quarry. The interaction types between the user and the system are related with the tasks of navigation, selection, manipulation and system control[2].

3 Development methodology

The development process of this system requires that, independently the extension and the domain of the problem, must be adopted an organized and composed strategy for their distinct phases, that allow to get

initial goals. Thus, after an adequate analysis of the domain of the problem, it was chosen the prototyping evolutive model [3], as the more adjusted methodology to the process of development of SimGrua.

Thus, it was identified and defined some different prototype versions of the system, each one with an different functional content. Below, are identified the different incremental versions of the system that had been implemented:

1. **Initial version** (Virtual Space 3D): Three-dimensional representation of the virtual environment of the quarry, with prominence for the following components: hole quarry, crane, stone blocks, park of blocks and all involving area.
 - **Goal:** to create the geometry of the 3D objects and to apply the appearance (textures) of the materials gifts in the space of the quarry, in efficient and trustworthy way.
2. **Intercalated version 1**(User Navigation): Implementation of techniques and interaction devices in navigation process of the user in the virtual environment.
 - **Goal:** To navigate in the virtual environment, on natural way, without provoking in the user physical fatigue and mental effort, and using the minimum number of possible navigation metaphors.
3. **Intercalated version 2** (Crane Operation): Implementation of mechanisms that allow the user to control the movements of the active components of the crane, using a physical interaction device named “buttons box”, that allows to simulate the cinematic and mechanical characteristics of these components (arm and cable/hook), when in operation.
 - **Goal:** To allow that the user controls the movements of the dynamic crane components, through the use of a similar device (“buttons box”) that is used in the real quarries and allows that in real time system reply to users data inputs.
4. **Intercalated version 3** (Collision Detection/Handling): Implementation of the mechanisms that allow the system to detect collision between active components of the crane and other quarry objects, like: hook/stones, hook/quarry wall, arm/stones, arm/quarry wall and arm/floor.
 - **Goal:** allow user to execute selection and translate stone blocks tasks, based with simple metaphors, as well, the system must detect manipulation errors provoked by inadequated user actions.
5. **Intercalated version 4** (Collaborative Work): Implementation of mechanisms that allow the crane operator to interact with assistant operator of maneuver, gift in the deep of the quarry, through a gestual and verbal language.
 - **Goal:** To allow that the crane operator and its assistant of maneuver can communicate, between each one of its virtual environments, and where the results of its actions must be propagated in real time.
6. **Intercalated version 5** (Pedagogical Exploration): Implementation of mechanisms that allow to explore some pedagogical resources of the system.
 - **Goal:** To allow that operator crane actions can be evaluated and monitored for the system and teacher, being able the system to be setup with some pedagogical options.

This type of methodology proved that it allows a good communication between requirements team and development team, minimizes the risk of the system if not adequated for final users and assures a better correspondence between the real world and the specifications.

4 SimGrua functional architecture

A great challenge in the virtual environment construction is the exploration and use of a panoply of different types of hardware and software technologies, based on some methodologies and techniques during the project phases. As it can be verified in Figure 2, the system was designed to use a set of different technologies that allowed to get initial goals.

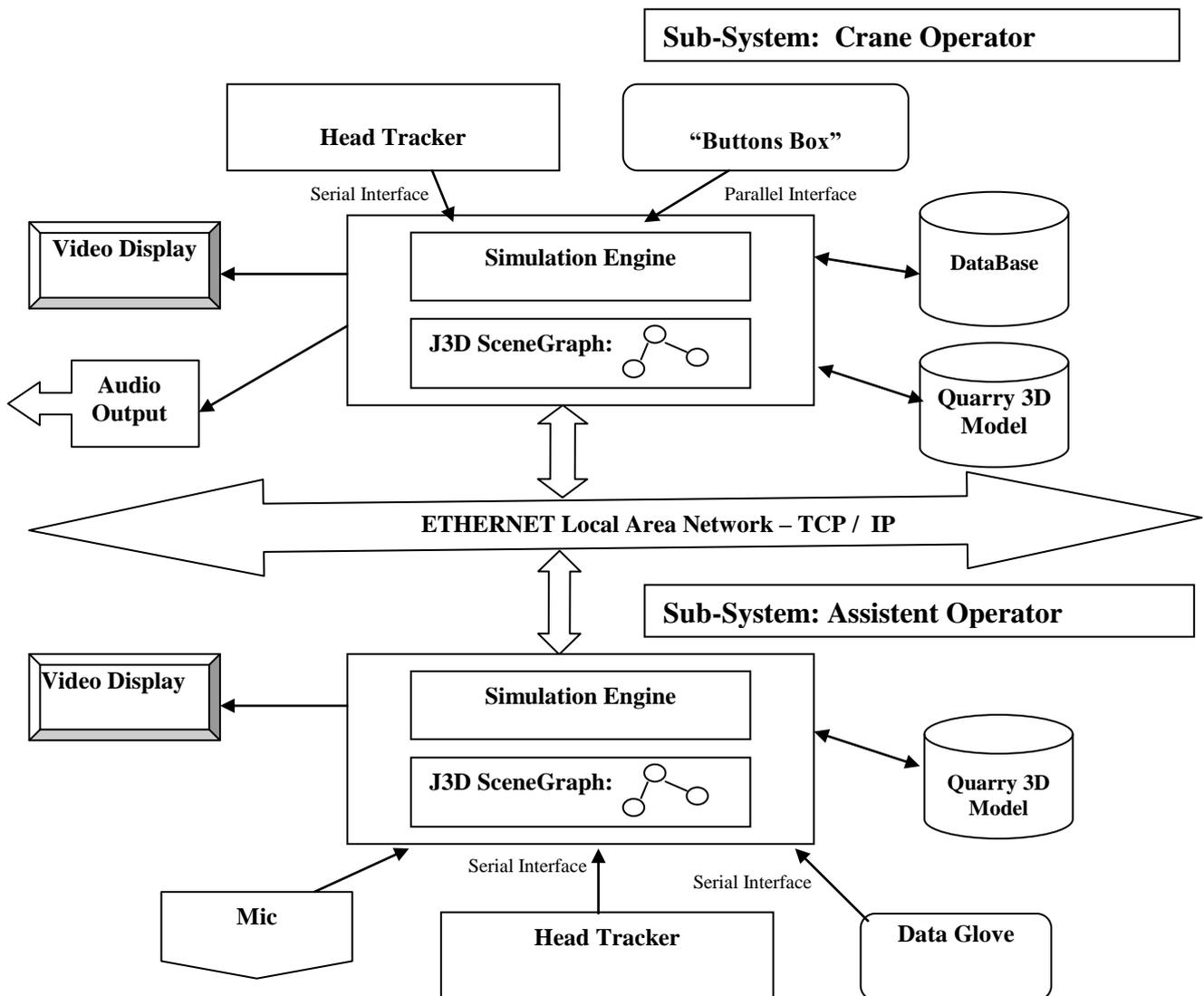


Figure 2. SimGrua functional architecture

It was designed to use different input and output peripheral devices, one conventional as mouse, keyboard, microphone and video display, and others not conventional like head tracker, data glove and "button's box". The use of each one of these devices tries to provide, in the execution of each task, the best interaction conditions for system users.

Although the navigation process in the virtual environment can use the keyboard and mouse devices, it was verified that the use of head tracker device and its associated interaction technique is more efficient for users in their tasks. The head tracker used was the Polhemus FastTrack.

The chosen device to control the crane mobile components (arm, cable and hook) is the "buttons box", that is the same type that it is used in the real quarries.

In the real environment a collaborative relationship exists between crane operator and his maneuver assistant. He uses verbal and gestual information to communicate with the crane operator during the execution of an translate stones operation, as way of preventing critical errors. The SimGrua is a multi-user system, who promotes the communication between at least two users and that allows the same ones, even so of different points of view, to see the same state of the virtual environment. This requirement is possible to implement if it uses paradigms of distributed programming. The implementation of the multi-user distributed system, had a physical support on local area network technologies based in TCP/IP (Transport

Control Protocol / Internet Protocol) protocols stack. The distributed programming was executed with resource Java package RMI (Remote Method Invocation)[4], that is a part of the core packages of Java programming language. It was designed to use a 3D data glove to capture the operation assistant gestual language and a microphone to capture its sonorous information, whose are transferred to the subsystem of crane operator through local area network.

The system functional core was based on a simulation engine, that supports three-dimensional visualization, management of users behaviors and the other objects of the system, management of different input/output physical devices and allows a multi-user collaborative tasks. The visualization engine was developed in the Java programming language, using for that, a API (Application Programming Interface) Java3D[5] in the following tasks: scenegraph creation, rendering cycle, management of inputs and outputs data from users interaction devices and management of behaviors between objects in the system (example: collisions). The 3D model of the virtual environment had been described in format VRML (Virtual Reality Modeling Language)[6]. The user visualization of the virtual environment is showed in video CRT (cathode ray tube) display.

The system also has mechanisms to manage the data generated by pupils and teachers, before, during and after the training sessions. These data are stored in a SQL (Structured Query Language) database given managed by the database management system MySQL.

5 Conclusion

The SimGrua was tested during its period of development by technician people of marbles extraction industry area and by training technician people. The tests was implemented in usability areas and in the system performance. In usability area the gotten results show us that the users level of satisfaction and their system learning level was sufficiently reasonable. In system performance area, some tests about different quarry 3D models was made, having as goal to get a model that became the system interactive. A visualization system is considered interactive if render between 15 and 25 frames per second. Thus, a three-dimensional model of the quarry was gotten that confers a reasonable performance to the system, assuring a level of acceptable realism in the tasks executed by the users.

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